Kurzbericht zum Forschungsvorhaben:

Preparation of a guideline for the development of user-friendly and practical structural design codes

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Die Verantwortung für den Inhalt des Berichtes liegt bei den Autoren.

Abridged report

Goal of the research

Over the past few years, users' discontent with design codes has become loud and clear. Complaints have been voiced about the increased scope of the codes and the amount of calculation work along with an increasing decline in their traceability and transparency.

On 1 July 2012, the first big package of Eurocodes will be introduced with binding effect for construction works. However, this will not lead to the hoped simplification and harmonisation of the codes. On the contrary, it will increase the number of codes and other applicable recommendations. The complexity and difficulties will consequently continue to grow because the European codes are usually more extensive than the preceding documents and are only applicable in combination with the so-called national appendices and supplementary regulations.

With this in mind the persons involved in the research project have put a great deal of thought into the topic of standardisation at the initiative of the Verband Beratender Ingenieure (VBI) (association of consulting engineers) and the Bundesvereinigung der Prüfingenieure für Bautechnik e.V. (BVPI) (confederation of test engineers for structural engineering) within the scope of the research initiative 'Zukunft Bau' (The Future of Building) of the Bundesinstituts für Bau-, Stadt- und Raumforschung (The Federal Institute for Research on Building, Urban Affairs and Spatial Development). Legal matters were clarified with the support of the lawyer G.-F. Drewsen.

The initial goal was to describe the current situation with its deficits, taking into account both the substance of codes and the structure of the sets of rules as well as the organisational forms and processes on whose basis the codes are formulated. Requirements that a code have to fulfil to allow safe building in accordance with the recognised standards of good practice were then defined. Concepts for future codes were then developed on this basis which shows, amongst others, how codes and code programs should be structured to guarantee efficient work with them. Possibilities were also identified as to how the application effort could be reduced. In a final step, an attempt was made to show possible organisational forms for the development of codes and standards. The aim was to create corresponding structures and processes that benefit today's international alignment of the creation of codes and standards.

Performance of the research work

The focus of our investigations lay in the program of the so-called structural design codes (Eurocodes), consisting of the basis of structural design and actions on structures codes as well as the various design codes. The work comprised the following three stages and topics:

- Analysis of the current situation and clarification of the marginal conditions for the development of codes in Europe and Germany,
- Development of a concept for future codes (technical level),

- Preparation of a proposal for the organisation of the development of codes (organisational level).

The research work was coordinated by the project management team (Dr.-Ing. V. Cornelius, Dr.-Ing. K. Morgen, Prof. Dr. Viktor Sigrist, Prof. Dr.-Ing. Martin Ziegler) and accompanied by the Advisory Board (Dipl.-Phys. Dr.-Ing. Karlhanns Gindele, Dipl.-Ing. Erich Jasch, MR Joachim Naumann, TRDir'in Dipl.-Ing. Brit Colditz, Prof. Dr.-Ing. E.h. Manfred Nussbaumer, Prof. Dr.-Ing. Karl G. Schütz, Prof. Dr.-Ing. Carl-Alexander Graubner); the Advisory Board met a total of three times. The research work began with the kick-off workshop on 28 September 2009 and ended with the closing event on 8 November 2011; both of these were held on the premises of the Bundesvereinigung der Prüfingenieure für Bautechnik e.V. in Berlin. Furthermore, the interim and final results were also presented at various symposia.

Summary of the results

Current codes

Unlike product standards and codes, thanks to which products can be manufactured that are reproducible and of a constant quality, design codes are a common basis for the designing engineers to determine the safety of the buildings they design. Design codes can have three main functions:

- **Administrative function:** The hierarchy and scope of the set of rules under consideration are defined.
- **Information function:** Communication between the persons involved in a building project is facilitated by codes. Codes also provide information on the state of technology.
- **Standardisation function:** A common basis is created which permits a comparison and evaluation of the computed safeties by specifying analysis and verification procedures.

The organisation responsible for standardisation on a national and international level in Germany in accordance with the standardisation agreement from 5 June 1975 is the Deutsche Institut für Normung e.V. (DIN) (German Institute for Standardization). In principle, anyone can apply to DIN e.V. to have a standard drafted. All that is needed is a concept for the standard and the basic funding. The draft has to follow certain formal principles of standardisation work that are set out in DIN 820. If there is a national interest in a standard that is being applied for, this will be forwarded to the steering committee of the pertinent specialist division in charge of the project for further processing. In the event of a positive finding, this passes the project on to the competent technical committee. This comprises all groups that are interested in a standard. A standard has to be adopted on the basis of a consensus to satisfy the legal requirement that the standard should document the recognised standards of good practice. If the standard that is applied for is in a European or international context, the standardisation committee is at the same time the contact for projects with the same content on a European or international level.

Requirements on structural design codes

Since the structural design codes (Eurocodes) do not deal with concrete objects or procedures, they have a special position within the standards. The requirements on this type of standard can be described as follows:

- **Safety:** The computed safeties that have to be observed are defined.
- **Standardisation:** Standard principles are to be defined for the analysis and verification procedures.
- **Legal certainty:** The recognised standards of good practice should be documented.
- **Quality assurance:** The application should guarantee compliance with minimum standards.

Consequently, a binding safety level must be observed when planning structural designs so that any risk to the life and health of the builder and user of the building as well as any third parties can be ruled out (with a socially acceptable residual risk). The safety should be calculated with the aid of standardised starting-point parameters and procedures; this will sensibly reduce the multitude of possible calculation methods to a manageable number. The economical assessment of a construction in compliance with a defined quality is to be guaranteed in this way. The standards are therefore a legally reliable basis for users in terms of the safety and quality of supporting structures.

In addition, standards are also an aid that should make the work of any planner (engineer) easier. The latter can be achieved by compliance with the principles listed below.

- The procedures and calculation methods described in the design codes should place the amount of work and the possible or necessary planning and computational accuracies in a better ratio.
- The design codes should regulate only those necessities that are imperative from a building authority’s point of view.
- The application of design codes in no way reduces the engineer's responsibility; the standards should offer decision-making help in questions that go beyond the direct filed of experience of the individual.
- The documents in the standards program should be consistent, i.e. they should be harmonious in themselves and there should be no contradictions between them.

A standard should explain those cases in which complex investigations are sensible and when they can be set aside. In the case of very dispersive inputs or inputs that are difficult to record, clear and simple calculations are often accurate enough; what's more, they are easier to interpret and provide a firm basis for any decisions that have to be taken. Standards should never take on the character of technical or text books. Nor are they intended as a vehicle to present the latest results of research. The following requirements exist on structural design codes from a formal point of view:

- **Legibility:** Texts of standards should be easily legible, understandable and concise.

- **Uniformity:** Standards should refer to uniform bases, should use uniform technical terminology and have a uniform document structure.
- **Traceability:** the (physical) relationships on which the analysis and verification procedures are based should remain identifiable.
- **Clarity:** There should be only one (possibly multi-stage) procedure per question that provides clear results.

Since new standards are usually within an international context and are therefore initially written in English, the linguistic accuracy (e.g. in the translation) is very important. After all, standards also contribute to a better understanding, another essential factor, which is reason enough for them to be consistent in their terminology.

Recommendations to improve the structural design codes

Structure and organisation

The European codes program for structural design comprises several documents which can basically be assigned to the following three groups of standards:

- **Structural design codes:** Bases for planning the structural design, actions on structures as well as design standards.
- **Codes for building materials, products and the execution:** Building materials (e.g. concrete, steel), construction methods (e.g. concrete structures, steel structures) and possibly special fields of application (e.g. buildings, bridges).
- **Test standards:** Technical testing of building materials and products.

This CEN concept should continue to form the basis of the structuring of structural design codes in future. One improvement that could be made relates to the hierarchy within the structural design codes, where geotechnical design is placed on a par with the other construction methods, even though geotechnical design enjoys a certain special status on account of the ambiguity relating to actions and resistances that often exist. Figure 1 shows a corresponding proposal.

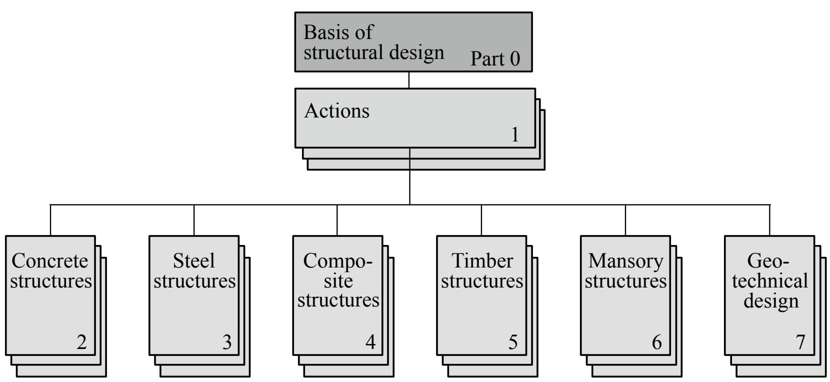

Figure 1: Recommended structure for structural design codes

The fundamentals of structural design form the basis for the use of the entire set of rules. Document 0 is superior to all other codes and covers not only the basic principles, e.g. to define representative values or on the safety concept, but also the basic procedure when designing structures. Rules on the actions are assigned to document group 1, which consists of several parts to allow a clear classification according to types of actions and application cases. Separate parts of this code should be drafted for the actions of fire and earthquakes.

A code whose subject matter is the analysis of structural design and the design relative to a construction method (e.g. steel structures) is called a design code. The design codes should cover all common construction methods, e.g. concrete structures, steel structures, composite steel and concrete structures, timber structures, masonry structures as well as geotechnical design. All of these codes relate to the document groups 0 and 1 and consequently have common principles and standard definitions. Each design code should be split into various parts, making for easier reading and limiting the scope of the individual documents. From today's point of view the structure should be broken down into four parts; the classification shown Table 1 by way of example for concrete structures is preferable.

Table 1: Structure of the 'Concrete structures' code

1	**Concrete structures – Part 1**
1.1	General design rules
1.2	Specifics for bridges
1.3	Specifics for tanks and silos
2	**Concrete structures – Part 2**
2.1	(e.g.) Supplementary rules for steel fibre reinforced concrete
2.2	(e.g.) Supplementary rules for ultra high performance concrete
2.3	(e.g.) Supplementary rules for fastening technology
3	**Concrete structures – Part 3**
3.1	Design for fire
4	**Concrete structures – Part 4**
4.1	Design of structures for the action of earthquakes

There are certain specific features for geotechnics due to the fact that work normally has to be carried out with the natural, in-situ substratum whose properties can only be changed within very narrow limits. Furthermore, actions can simultaneously be resistances and summary parameters derived from the material strengths are usually used as the resistances in limit state equations for the individual geotechnical constructions. This makes it difficult to adopt the structure of the structural design codes directly for these applications. Nevertheless, the aim should be an at least analogous structure.

Safety concept and structural design method

Today's standards are built-on the so-called semi-probabilistic safety concept that calls for verification with partial safety factors and which pursues the idea of taking the deterministically defined influencing variables (e.g. load, strength) into account in the calculation depending on the probability of their occurrence. The partial safety factors record the scatterings of the material properties, the geometrical parameters and the effective loads, though also the inaccuracies of the load and resistance models in a simplified way.

Verification is needed to evaluate structures, their parts and connections, whereby these relate to the limit states of the load-bearing capacity and the serviceability. The following types of ultimate limit states should be considered:

- the loss of the equilibrium of the structure (EQU),
- the failure of the structure and/or its elements (STR),
- the failure (or excessive deformation) of the substratum (GEO) and
- the fatigue failure of the structure and/or its elements (FAT)

In geotechnics, the loss of the equilibrium of the structure (UPL) and failure through hydraulic shear failure (HYD) may also be important. The limit state of the serviceability (SLS) includes compliance with the so-called working limits. The verification generally consists of comparing structural design values of the actions (or of loads) with those of the resistances. The respective characteristic values should be raised or reduced by the partial safety factors; Figure 2 **Fehler! Verweisquelle konnte nicht gefunden werden.**shows the procedure that was developed for this within the scope of work on the Eurocodes. It is clear that the structural design values can be formed in different ways.

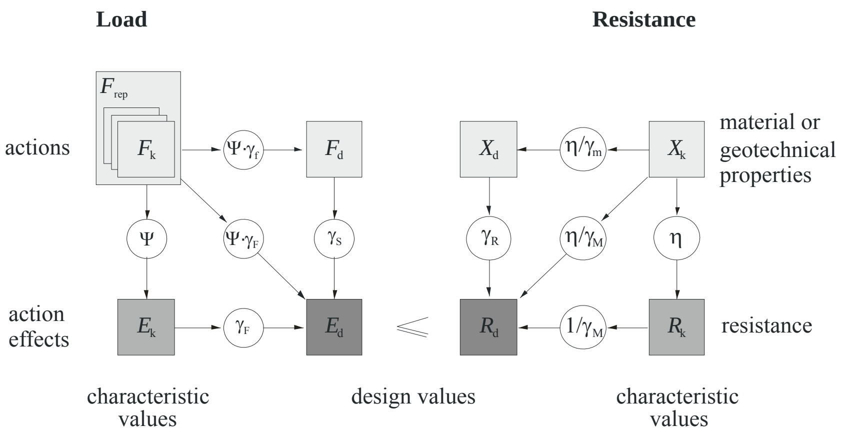

Figure 2: Possibilities for forming structural design values

When dealing with the actions, the semi-probabilistic safety concept allows partial safety factors (that are based on probabilistic examinations and thus take into account the relevant scatterings) to be specified depending on the action. Furthermore, the actions can be combined with each other taking individual uncertainties into account. This procedure in any case increases the calculation work, though not necessarily the accuracy. One criticism that is often brought up relates to the partial safety factors for actions: when verifying the load-bearing capacity these are normally γ_F =1.35 for dead loads and γ_F =1.50 for live or traffic loads. One could ask whether the partial safety factors can be replaced by a single value γ_F without any significant loss of safety and efficiency. In the event of proportionality between the action on and action of, and assuming that the uncertainties on the resistance side can be covered with only one safety factor

γ_M, it is possible to work with the product $\gamma_F \gamma_M$ (if the combination factors are initially ignored). This procedure should remain admissible.

Further important components in the safety concept are the combination rules (with the combination factors ψ). The introduction of the combination rules leads to some resentment in practice; critics complain about the number of rules and the fact that the combination values are too large, something that greatly aggravates the interpretation of the (computed) results. Simplified combination rules can be derived on the basis of comparative calculations. For example, a (universal) combination factor can be used for common cases and known construction tasks (e.g. buildings).

DIN 1054 (2010) also allows to give the actions combination factors in geotechnics. The representative actions determined in the design of the structure that have already been assigned to combination factors should be adopted directly. However, the additional possibility of assigning combination factors to the geotechnical actions too has to be questioned. Since the constant actions of soil and water pressure normally dominate the geotechnical actions, the effect of the combination factor on the results is slight.

Recommendations on how to improve the standardisation work

The current organisation of standardisation work has to be questioned and the necessity of improvements in the process is undisputed. The work has to be intensified in terms of personnel and time in such a way that this embraces the goals and claims of standardisation. What are needed are representatives of the interested groups, in particular in the field of the executive firms and engineering offices, who are willing and able to perform the corresponding work. It goes without saying that this highly qualified work has to be paid for; the legwork for standards has to be seen as an engineering service with specifications and fixed, agreed deadlines for completion that are regulated in a corresponding agreement.

There are two basically different options (models) for the organisation of this legwork:

- In the **Support Model** (also called the standardisation initiative practice 1 or **NIP-1**), as many groups as possible who are interested in the standardisation contribute to financing a fund. Each of the main standardisation committees in DIN e.V. will then be assigned a budget from which orders with clearly defined tasks can be placed with competent, specialised engineers. A full-time director should be employed to coordinate these orders. On the whole, this model would correspond to a (professional) expansion of the existing DIN committees. The fact that not all of the interested parties are involved equally and that the results may be biased towards certain interests could prove to be something of a problem.
- With the so-called associations model, the legwork for the standardisation committees would be carried out on the basis of interests by those groups whose work is most affected by the standards, and it should be largely financed and organised by these at their own responsibility.
  Two options are conceivable with this model, one being the so-called **overall associations model** (or **NIP-2a**). Those groups that are especially affected by the standardisation or their associations hereby form an organisational unit where the legwork for the standardisation

takes place. The employees of NIP-2a will be delegated by the member companies for a certain period of time or will be taken on especially for this work; they are under the control of the director. The principle of solidarity applies for the work, in other words, all of the professional associations support the work, irrespective of which topic is currently the focus of activities. The professional and strategic guidelines will be defined in agreement with a steering committee.

Another option is the **professional group-based associations model** (**NIP-2b**). In order to cater for the very different interests of the associations, the activities of NIP-2b will be adapted to the commitment of the individual professional groups. This means that the professional associations only co-finance those activities that lie within their narrower interests. The fixed-term work will be carried out by employees from the companies; external advisers can also be consulted by the project group if necessary. A share of the contributions from the individual groups will be retained to pay a full-time director who coordinates the activities together with the steering committee.

It should be noted that whilst this project was still under way (on 13 January 2011) the initiative 'Praxisgerechte Regelwerke im Bauwesen e.V. ('PraxisRegelnBau' for short = practical rules in building work) was founded (press release of the DBV from 18.01.2011). Ten professional and planning engineer associations are currently involved in this initiative along with the construction industry and building trade. Its organisational structure is similar to that of NIP-2b.

The professionalisation of standardisation is the most effective method to sustainably improve the rules and standards. This enables uninterrupted work at a high level so that the standardisation work can be accelerated. All of these activities should be carried out in close collaboration with the national standardisation institute DIN e.V., whereby the first thing that has to be done is to develop a joint strategy for user-friendly and practical documents. It is absolutely essential that the nationally developed concepts are integrated in the European standardisation process as early as possible. Going it alone on a national level is contrary to European legislation and therefore doomed to failure from the very outset. It is therefore recommend to enable a long-term and professional involvement of German representatives as far as possible since it will increasingly become a matter of representing national interests over longer periods and in as qualified a manner as possible.